Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 11 (2013) 8 – 14

www.elsevier.com/locate/procedia

2nd International Through-life Engineering Services Conference

Sustainable service system for machine tools

Masahiko Mori*[a], Makoto Fujishima[a]

[a]*MORI SEIKI Co., Ltd., Nagoya, Japan*

* Corresponding author. Tel.: +81-52-587-1811; fax: +81-52-587-1818. *E-mail address:* fujisima@moriseiki.co.jp

Abstract

Quick and correct service is most important for machine tool users. In order to maintain efficiency of machine tools at customers' sites, remote maintenance and monitoring system, worldwide spare parts supply system, integration of service parts, education system for service engineers, long-term environmental load reduction are necessary. This paper presents current and future activities of machine tool manufacturers for improving the service system.

Selection and peer-review under responsibility of the International Scientific Committee of the "2nd International Through-life Engineering Services Conference" and the Programme Chair – Ashutosh Tiwari

Keywords: Maintenance; Monitoring; Service parts

1. Introduction

Machine tool technologies have been significantly advanced in the past 20 years. Technological innovation—high-speed machining, 5-axis machines, multi-axis machines, direct drive motor, CNC technology, high-resolution absolute-value encoder, and CAD/CAM—enables us to perform high-speed, high-accuracy machining of complex-shape workpieces. Furthermore, innovative manufacturing technologies including hybrid machining combined with electrical, physical, or chemical process such as Additive Manufacturing, laser, and ultrasonic are expected to contribute to sophistication of products.

More machine tool manufacturers have been located in Europe and Asia including Japan. The three major countries account for 65% of the worldwide production volume - China accounts for the highest 27.3%, Japan for 23.5%, and Germany for 14.9%. If the countries in the fourth and fifth places are included, the worldwide production volume accounts for 75% or more: Taiwan accounts for 6.8% and Korea for 6.2%—this is the current status. On the other hand, the consumption rates of machine tools are 45.1% for China, 10.2% for America, 8.7% for Japan, 7.9% for Germany, and 6.0% for Korea. China manufactures machine tools and also half or more machine tools they use are imported. The U.S.A., the second largest consumer of machine tools, mostly relies on import. Japan and Germany exports 50% or more of manufactured machine tools and Taiwan also mainly exports. This current situation indicates that machine tool manufacturers need to run a global business. The key challenge for the future is providing prompt and accurate services for machine tools on the global basis.

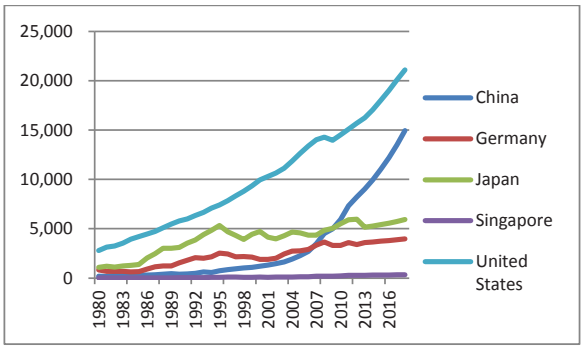

Fig. 1. Transition in the world GDP by country

Selection and peer-review under responsibility of the International Scientific Committee of the "2nd International Through-life Engineering Services Conference" and the Programme Chair – Ashutosh Tiwari
doi:10.1016/j.procir.2013.07.072

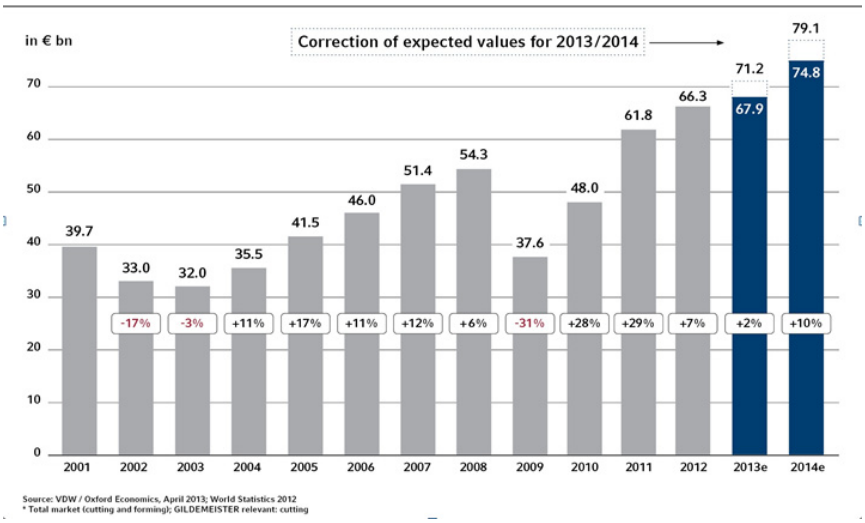

Fig. 2. Transition of machine tools consumption

Figure 1 shows the transition in the world GDP by country. In Europe, the U.S.A., and Asia, continuous smooth growth is expected, but stagnation is expected in Germany and Japan. Japan, in particular, slightly increased its GDP between 1997 and 2002 since the downturn resulting from the bursting of the bubble economy of the 1990s. The difference in GDP between Japan and the U.S.A. was approximately 2,000 billion USD from the 1980s to the mid-1990s, but now the difference is as much as 10,000 billion USD. China's GDP also exceeded that of Japan in 2010 and the difference became as much as 30% in 2012. Furthermore, it is expected to be doubled in 2015.

Figure 2 shows the consumption of machine tools in the world. The consumption continued to grow and reached 54.3 billion USD, but dropped by more than 30% to 37.6 billion USD in 2009 due to the U.S. subprime loan issues. After that, the consumption started to recover in 2010 and reached a record high of 61.8 billion USD in 2011 again; and it is expected to grow further. As we look at the global consumption of machine tools, it may drop temporarily depending on the economic situation, but keeps growing. This paper introduces MORI SEIKI's approaches to the machine tool business.

This paper also describes improvement in the global service by utilizing remote maintenance and monitoring system, worldwide spare parts supply system, integration of service parts, education system for service engineers, and long-term environmental load reduction.

2. Collaboration with DMG

2.1. Sales and manufacturing

Gildemeister AG (hereafter referred to DMG), established in 1870 is a German company with 6,500 employees and annual sales of 2.2 billion USD; MORI SEIKI, established in 1948 is a Japanese company with 4,500 employees and annual sales of 1.9 billion USD. Both companies have been collaborating together, and to further strengthen the collaboration relationship, we will increase the shareholding ratio of each company and change the company name to DMG MORI SEIKI [1].

Figure 3 shows the DMG MORI SEIKI sales network. The total of 6,000 employees will work for the sales, application engineering, and service sections and the back office: 4,000 DMG employees and 2,000 MORI SEIKI employees. The world will be segmented into 1,000 small regions. These 6,000 employees will be all assigned to work in these regions to offer meticulous services, aiming to provide further qualified sales and services to the customers.

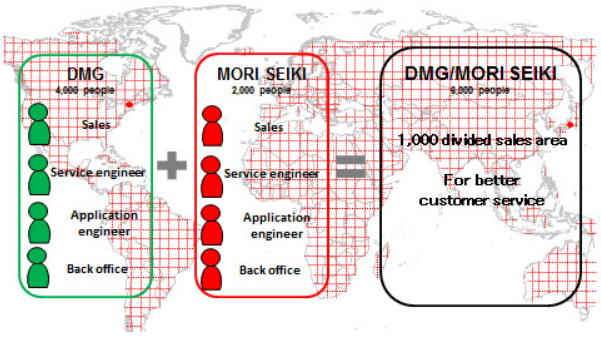

Fig. 3. DMG MORI SEIKI sales network

Figure 4 shows the global manufacturing facilities of DMG MORI SEIKI. Our production capacity is 6600 units/year in Europe, 6,000 units/year in Japan, and 3,000 units/year in China, and 1,000 units/year in the U.S.A. This enables us to ship machines from the most appropriate plant depending on

the exchange rate and transportation cost so that we can build the system to increase our profit under any circumstances.

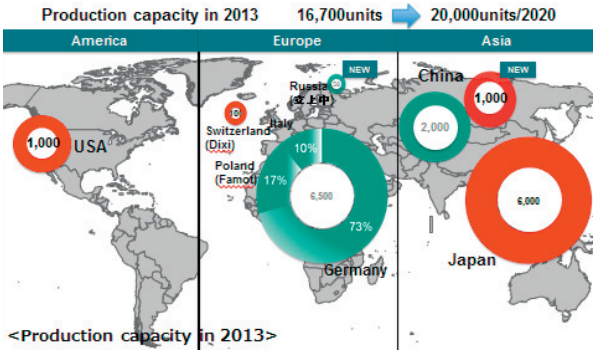

Fig. 4. Global manufacturing facilities

2.2. New manufacturing method

MORI SEIKI has been manufacturing machine tools using mainly the cell production system because machines are custom-made based on the specifications customized for customers. Meanwhile, we started the line production system to manufacture turrets, spindles, and some machine models because it is much more efficient for manufacturing units whose production amount is secured by using common parts. Figure 5 shows the spindle production line. The line production system allows production of 12 units/day, contributing to the increase of production efficiency by 30%.

Fig. 5. Line production system for spindle unit

2.3. Procurement cooperation

MORI SEIKI has been manufacturing machine tools almost 100% in Japan and procuring most of the parts in Japan on a yen basis. On the other hand, the export ratio of machine tools is 70% and we receive payments for the machine sales almost equally in yen, U.S. dollar, and euro, thus exchange fluctuations largely influence the profit. Therefore, we will procure some of the parts in euro and U.S. dollar, as much as 15% of the entire parts, aiming for being less vulnerable to exchange fluctuations.

In the past, we would procure parts by MRP for a single machine according to the specifications exclusive to a customer. Enhancing the accuracy of production plan, decreasing the number of custom designs by using packaged specifications, and common use of the major parts now allow us to procure them in bulk and to lower the parts price. We have implemented this scheme in mass-production models, and we are planning to procure 50% of the entire parts in bulk.

3. Remote maintenance and monitoring system

Figure 6 is a bar graph representing the number of MORI SEIKI machines delivered to each region in FY 2011. As you can see in the graph, the number of machines delivered inside Japan accounts for approximately 30% of the total machine delivery [2, 3].

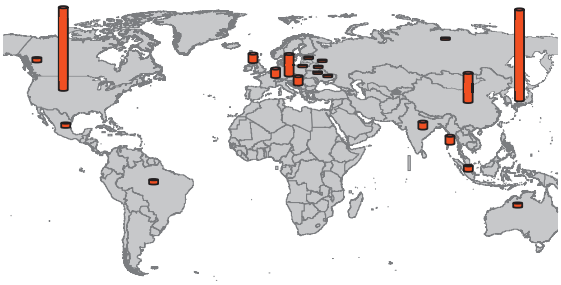

Fig. 6. Distribution of installed machines

There is a significant difference in maintenance man-hours between domestically-delivered and exported machines.

MORI SEIKI has 44 service bases across Japan, where some 30% of the machines sold are used, to support domestic users, while covering all overseas users with its 90 service bases worldwide. An overseas base needs to cover a far larger geographical area than a domestic base. For example, in the U.S.A., which is about 25 times the size of Japan, the whole country is covered by as few as 14 service bases. When a machine tool breaks down, on-site repair is generally required; if industrial equipment, including machine tools, stops working due to malfunction, swift recovery is of utmost importance. Thus, for machine tool manufacturers relying heavily on overseas markets, it is urgently required to expand their overseas service bases and improve service efficiency. In order to do so, the ideal solution is to acquire operation status of the customers' machine tools to diagnose and analyse remotely at manufacturers' service bases so that preventive maintenance is promptly conducted online. It is obvious that the current communication technology, such as the Internet and the mobile Internet devices, e.g. smart phones, provide the full possibility to connect the manufacturer and the customers' machine tools together. Therefore we are developing efficient service system, which is called Industrial Product Service System (IPS2) [4]

MORI SEIKI is proceeding with collaboration with DMG, and we are trying to work in the same environment including the remote maintenance system. Figure 7 shows the new architecture of DMG MORI SEIKI Netservice. It consists of several portions: machine/customer information system, remote DMG MORI SEIKI machines, DMG service centers and MORI SEIKI service centers all over the world.

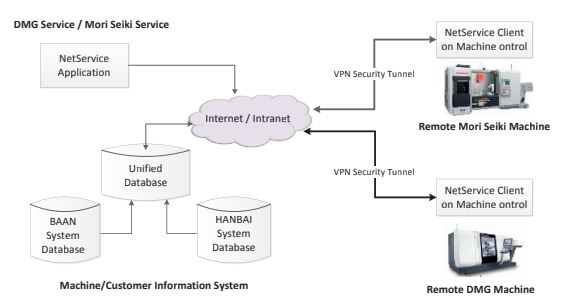

Fig. 7. DMG MORI SEIKI Netservice new architecture

The machine/customer information system is the foundation. Machine tool data of each company with the corresponding customer information are merged from two separate databases into one unified database system. Machines already shipped will be equipped with an application named NetService Client which allows DMG MORI SEIKI service centers to remotely log on to perform maintenance service such as fault diagnosis, system update, option validation. During the remote service, service engineers can easily build the complete service scenario by referring to necessary machine/customer information in the unified database. This dramatically improves the service work and gives customer better experiences. The connection between remote machines and service centers is established via the Internet VPN tunnel, therefore the security for customer data is also ensured.

4. Worldwide spare parts supply system

The average life-span of machine tools is considered 15 years and long-term maintenance is required. Since machine tools are production facilities, quick recovery of them is necessary whenever troubles occur. We have a customer service office at the Iga Campus. Customers can call us at the toll free number and veteran service engineers always stay there to support customers for 24 hours a day and 365 days a year. Our veteran service engineers support customers by utilizing information of customers' machines and records of repairs in the database as well as know-how. When we determine that we need to send parts or dispatch service engineers to customers' sites, we arrange to send parts from the Global Parts Center in Nara Japan or dispatch service engineers from technical centers via the Intranet. We set a target rate of our service engineers leaving for customers' sites within 24 hours after receiving calls for service at 90%. To achieve the rate, we select those who are able to reach the customers fastest from across the nation and immediately dispatch them.

Information we receive from customers daily is stored in the database and classified into machine records by customer. We store information on customers, delivered machines, and record of repairs in the database daily to reduce time for solving problems. Currently we can solve 70% of problems on the telephone.

At the Global Parts Center in Nara Japan—the main base of our parts centers—after we receive an order of replacement part, we identify the part, check for the stock, and arrange to send it to the customer or the nearby technical center. We are supposed to ship parts within 24 hours after an order is placed and we ship 95% of the total orders accordingly (Figure 8). The area of the Nara Parts Center is 12,330 m^2, the number of employees is 72, the parts we keep are 120,100 kinds, and the amount of stock is 18,400 million yen and we provide service parts to DMG MORI SEIKI worldwide including service parts for machine tools of Hitachi Seiki.

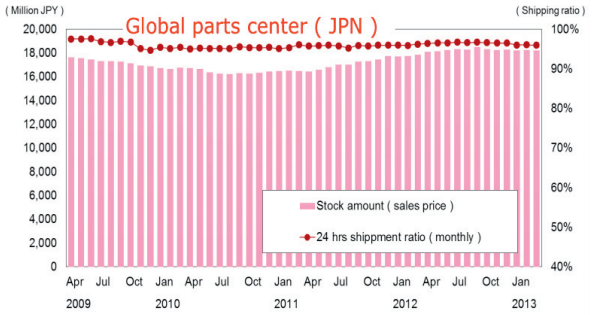

Fig. 8. Parts shipping ratio within 24 hours

If we ship all the parts from Japan to all over the world, we will have problems of shipping cost and delivery time. To solve these problems we have parts centers in the U.S.A., Germany, Thailand, and China. Figure 9 shows the locations of our parts centers.

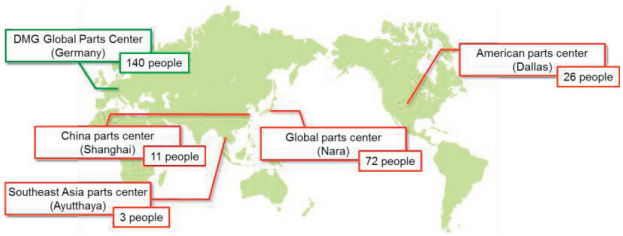

Fig. 9. Locations of Parts Centers

5. Integration of service parts

Although models of machine tools are changed relatively less frequently, well-selling models are usually upgraded in seven or eight years. Every time models are upgraded, we need to prepare new service parts. Providing the following parts are extremely important: the spindle, a core part of

moving sections; the unit including electronic parts, many of which are often discontinued. To provide these service parts efficiently, we integrate parts and apply new units to old machines.

5.1. Integration of spindles and application to old machines

Figure 10 shows the No. 40 taper spindle for machining centers of MORI SEIKI. The speed, output, torque, and shape have been optimized for each machine, resulting in as many as 304 types of spindle units, which requires tremendous labor force and cost for providing service parts. Therefore, we started to reduce the number of spindle types that are used for the machines still being manufactured as well as for the old machines. First, the 304 types of spindles are disassembled into spindles and draw bars—71 types of spindles and 94 types of draw bars. Then stators are classified into two categories of different diameters, φ180 mm and φ240 mm, and in each category groups are made by length: groups S, L, LL, 3L, and XL in category of φ180mm; groups S and L in category of φ240mm. Integration is considered by group.

More importantly, previous spindles are manufactured in low volume as service parts, but when the series of integration is completed, the spindle for the latest model can be used as a service part for old machines, leading to drastic reduction of the production process. Furthermore, although the latest spindle has been upgraded to the one with high-speed, high-rigidity, and high-accuracy performance, the latest technology like this can be applied to old machines after service parts are replaced, enabling us to offer better services.

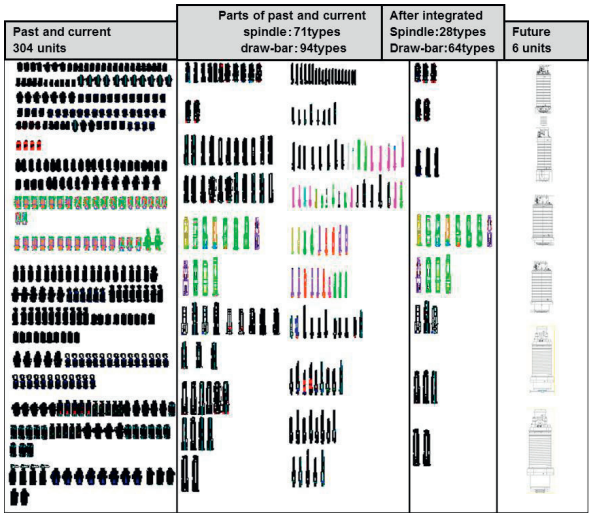

Fig. 10. Variation of No. 40 taper spindle for machining centers of Mori Seiki

5.2. Management of service unit including electronic part

MORI SEIKI machine tools are equipped with unique HMI called MAPPS. This enables the remote maintenance mentioned in Section 3 and uniformed operability without depending on CNC manufacturers. Also, MAPPS facilitates operation of machine tools, which often requires special skills, by utilizing CAM or automatic programming system, and furthermore, it provides know-how of expert engineers (Figure 11).

Fig. 11. Human Machine Interface（MAPPS）

The MAPPS HMI uses computer technology, so the model has been changed almost every three years since its launch in 2000 and currently the hardware is the fourth generation. Storing the components and servicing them would be difficult considering a rapid model-change cycle of electronic parts; therefore we designed from the beginning so that the latest unit would be also applicable to old machines. Figure 12 shows the MAPPS and CNC structures. API (Application Interface) is compatible and remained compatible even after MAPPS hardware or software is revised.

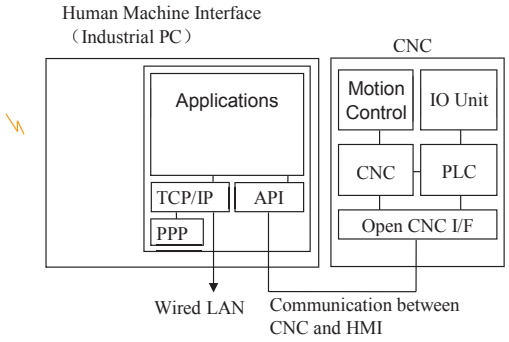

Fig. 12. Structure of MAPPS system

Therefore, hardware or software for older generation is replaceable with the latest one, and thus it is not necessary to store old electronic parts or units. The crucial point is that the maintenance makes it possible to offer the latest technology to customers.

6. Education for service engineer

When conducting business in the global market, it is sometimes difficult for service engineers at the front to understand every latest technology; therefore education of service engineers is very important.

MORI SEIKI provides the education service for customers, sales persons, and service engineers at three locations: Japan, Germany, and the U.S.A. It is mandatory for service engineers to take a training course twice a year where they learn the latest machines and technique for NC controllers so that they can efficiently provide good service to customers. Subjects for courses vary and the following examples show the ones for three to five day courses. Individual service engineer selects the best suitable course for their skill enhancement.

1. Syllabus for Class I, five-day course

Safety: rules for service engineers based on the education manual for service engineers, education for a visit to customers

Education on safety points at work, case studies of injury accident, hazard prediction

- Recovery procedures after interference occurs on NC lathes (Headstock, turret, tailstock, zero point, pre-setter)
- Electrical maintenance (electrical circuit diagram, I/O diagnosis, trouble diagnosis procedures, trouble shooting)
- Procedures for pitch measurement and setting the zero point after replacing ball screws on vertical machining centers
- Bearing monitor analysis

2. Syllabus for Class II, five-day course

- Safety: rules for service engineers based on the education manual for service engineers, education for customer visit
- Education on safety points at work
- Installation; accuracy inspection; adjustment of each squareness; check and adjustment of spindle tilt, B-axis tilt, and C-axis center; setting 5-axis parameter; magnetic pole adjustment, adjustment of synchronous, laser measurement
- Bearing monitor analysis
- MAPPS trouble shooting and installation of software

3. Syllabus for Class III, three-day course

- Safety: rules for service engineers based on the education manual for service engineers, education for customer visit
- Education on safety points at work
- Feed axis adjustment (DBB, laser measurement, servo guide), bearing monitor
- MAPPS trouble shooting and installation of software

Through these training classes, we aim at expanding knowledge of service engineers so that one engineer can maintain various parts on various machines by himself. There are five kinds of machine tools: NC lathes, vertical machining centers, horizontal machining centers, multi-axis machines, and 5-axis machining centers. The required skills for service engineers are: mechanical maintenance, electrical maintenance, CNC maintenance, operation, programming, and installation. These skills are categorized into 50 items. We evaluate service engineers on these 50 items by marking 0 to 2 points for each item with a total of 100 points. A service engineer is dispatched alone only if they have 1 point or more in the item for the concerned service. The service engineers' target for skill points is 80 or more.

Table 1 Skill table for service engineer

No.	Category	Description	Detail
31	Electrical	Measurement	Volt Meter, Phase Checker, Clamp Meter
32		Trouble Shooting	Reading Electrical Drawing
33			DGN / Ladder (Fanuc)
34			DGN / Ladder (Mitsubishi)
35		Software	NC & MAPPS Software Update
36			Data Back Up & Restore
37		Electrical Special Option	High Pressure Coolant
38			Additional M-Code
39			Additional 4th / 5th Axis
40			Bar Feeder
41	Mechanical	All	Ball Screw Replacement
42			Axis Zero Point Adjustment
43			Spindle Balancing (Vibro Tester)
44			Laser Measurement / Pitch Error Compensation
45		Lathe	Turret Alignment
46			Headstock / Tailstock Alignment
47			Spindle/Chuck Replacement
48		Machining Center	ATC/Magazine Alignment / Adjustment
49			APC Alignment / Adjustment
50			Spindle/Draw Bar Replacement

7. Long-term environmental load reduction

Among general machine tools, only a few are equipped with a power monitor. We are trying to feedback power consumption on machine tools to the NC units in order to reduce power consumption. Figure 13 shows the system for monitoring power consumption. A clamp-type current sensor is attached to the input power source and connected to a printed-circuit board called data collection unit. Current sensors have analog signal output 0 to 10V and generate voltage in proportion to the current. From the signal, the power consumption is converted in the data collection unit and sent to the panel computer on the NC display via Ethernet. Power consumption is displayed on the NC display so that, for example, it is possible for an operator to know the required electric power for machining one part. Furthermore, MORI SEIKI receives information about power consumption as well as NC operation status via the Internet in order for the customers to use electric power more efficiently. For example, the machine can be automatically turned off, if the power is still on after a program is ended, by utilizing information about power consumption and operation status. Thus, wasted standby power is decreased. Or, if machine operation such as the chip conveyor is still running after machine is stopped, it can be monitored.

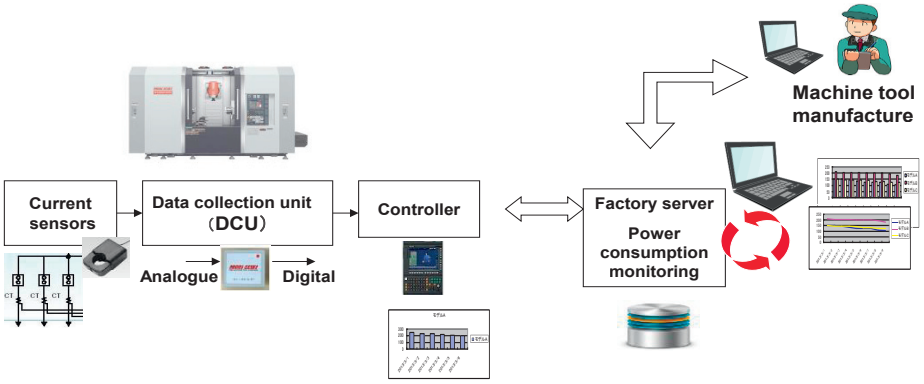

Fig. 13. Power consumption monitoring system

8. Conclusions

For enhancing the service quality of machine tools, the followings are necessary:

- Service structure
- Quality of engineers
- Parts supply
- Integration of service parts from design.

Note that the value of machine tools is not only their quality, but also application supply and service that are accompanied.

References

[1] M. Mori, 2013, Business Activity for Global Machine Tool Market, MTTRF annual meeting
[2] M. Mori, M. Fujishima, M. Komatsu, Bingyan Zhao, Yadong Liu, 2008, Development of Remote Monitoring and Maintenance System for Machine Tools, Annals of the CIRP, 57/1
[3] M. Mori, M. Fujishima, 2012, Remote monitoring and maintenance system for CNC machine tools, 8th CIRP Conference on Intelligent Computation in Manufacturing Engineering
[4] M. Fujishima, K. Hanaoka, M. Komatsu, 2004, A Maintenance System for Machine Tools in the 21st Century, 2004 Japan-USA Symposium on Flexible Automation